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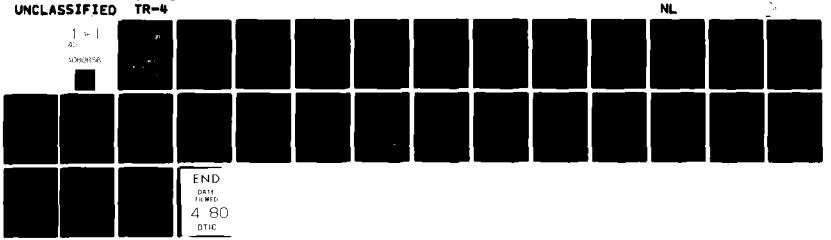

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Center for Cognitive and Perceptual Research

University of Oregon

Eugene, Oregon 97403

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LOW COST SIMULATION OF PILOTING TASKS.

Gerald M. Reicher

Brian J. Davidson

Harold L. Hawkins

Gilbert Osgood

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An attempt was made to validate a low cost, low fidelity, computer driven flight simulator. The validation is required so that the simulator can be used as a criterion task to see whether we can predict flight performance on the basis of performance on other tests of individual cognitive ability like attentional flexibility, visual representational skill, priority setting and planning. The simulator was based on instrument flying rather than visual contact flying and incorporated secondary tasks to further tax the pilot's capacity. Simulator performance is correlated with hours of flight training, the best correlations coming from conditions which impose additional task demands.

Low Cost Simulation of Piloting Tasks

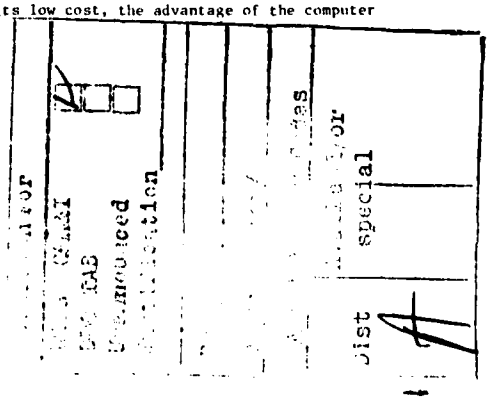
Gerald Reicher, Brian Davidson, Harold Hawkins, Gilbert Osgood[1]

University of Oregon

The present study is part of a larger project aimed at the analysis of complex skills into component abilities and the prediction of performance on the complex skills by tests of the component abilities. The abilities in which we are most interested are cognitive abilities (e.g., such as representational skill, attentional flexibility, timesharing ability, executive abilities). We feel that these abilities are very important in many tasks which superficially seem to be primarily motor performance tasks (e.g., team athletics, piloting an airplane, driving an automobile, or operating other complex machinery).

Although the conceptual problem of breaking down complex tasks into component abilities does not require that the complex tasks be practical ones, obviously the spin off from this type of research would be much greater if important practical tasks were analyzed. We have taken the task of piloting an airplane as an example of an important practical task. This report describes an attempt to validate an inexpensive flight simulator. If "flying" the simulator proves highly related to piloting, it will make sense to attempt to predict simulator performance on component tasks. Besides its practical importance, piloting has the advantage of being well-studied and of having many valid simulations reported. It also has well-defined component tasks and seems to require the sorts of cognitive component abilities we wish to study.

A review of the literature on flight simulation suggested that we could use our laboratory computer to simulate pilot performance tasks effectively and inexpensively. Aside from its low cost, the advantage of the computer



over more specialized high fidelity alternatives were flexibility for measurement or training and portability.

Our support for this thinking comes from a variety of sources. It is clear from the huge simulation literature that well thought out simulators can be a training aid. For example see Crawford and Brock, 1977 for a recent review. Povenmire and Roscoe, 1971 for simulator training in primary flight training, Reid and Cyrus, 1974 for formation flight training, Trollip, 1977 for training on holding patterns; Ketchel, 1977 for air combat training. Many simulators are designed to look and act as much as possible like an airplane. The large simulator at Williams Air Force Base is perhaps one of the extremes in fidelity in on the ground simulators. However, there are reports of good performance of small computer based simulations in predicting performance on the large simulators and on training. The people at the Human Resources Laboratory at *Williams report* that the small computer based simulation developed at Arizona State when informally evaluated seemed to be a good predictor of performance on the large simulator. This is not to say that these inexpensive simulations could take the place of the large simulators in specific advanced training or familiarization exercises which go on at Williams and with the Air Combat Maneuvering Range Program. But it may be an indication that the general skills needed to fly airplanes might be assessed and trained by using inexpensive computer simulations.

There has been a clear message in the literature that in training, considerations of task analysis and training design can be more important than realism (see Caro, 1973). Recent examples come from Trollip, 1977 and Finnegen, 1977. They showed that training on holding patterns could be effectively

carried out using computer aided instruction which did not emphasize fidelity at all. They emphasized (as did Caro) that for the purposes of training, the computer can do things which most simulators cannot in that they can provide a more effective learning environment by optimizing feedback and the like. The flexibility to allow maximization of learning or measurement parameters can be very important as long as the essential aspects of the task to be learned or measured have been successfully abstracted and incorporated. Our research assumes that the abstraction of component abilities is possible and can be done practically. The ability to arrive at good predictions of pilot performance with an inexpensive, unrealistic model is one test of this assumption. More stringent and interesting tests will be to see whether we can abstract and isolate general cognitive components useful in a variety of other skills. Support for useful abstraction of general cognitive abilities as components of piloting comes from Taylor and Parker (1959) for spatial tests as predictors of training success. Fleishman and Ornstein (1960) found factors predicting pilot performance were control precision, spatial orientation, multi-limb coordination, response orientation, rate control, kinesthetic discrimination and Gopher and Kahneman (1971) found that differences in attention predicted advanced placement of pilots.

Early in our research we tried to obtain one of several practical working simulations. These were either not available or not compatible with our equipment. We then wrote our own simulator for use on our laboratory computer and the studies reported were done on this version. Due to computer problems on the laboratory computer one of us is currently implementing a second version on his TRS 80[3].

Our primary target for this research is the more sophisticated pilot and we have arbitrarily designated the instrument pilot as reaching this level of sophistication. Thus, we are not just looking for someone who can drive a plane but someone who can deal with other complexities at the same time, as would any pilot flying for military or commercial purposes. Thus, we have made our simulation task very demanding. Maintaining direction is made demanding by stiff simulated winds and by simulated turbulence. A secondary computation task is also required. Subjects are given a speed and a distance and asked to compute the time required to fly the distance. In most cases where a decision had to be made about how close the simulator should be to the real thing, we decided that the cognitive task should be similar but the motor task different. Subjects maintain direction with two push-buttons, one for each direction. Instrument and control dynamics are not those commonly found in planes. Finally, calculations were not made on a flight computer and the procedures were different than is commonly used.

Our expectations were that the simulator tasks without secondary tasks would not be as related to flight proficiency as would the simulator tasks with the secondary tasks. In general, we expected the more demanding tasks to be more discriminating. These expectations came from the belief that tracking ability alone would not be a good indication of advanced performance on a flight task whereas the ability to deal with task complexity would. In preliminary work we found that people seemed to rely on some type of visualization ability even for direction maintenance on the simulator. The logic of instrument flying and earlier research (e.g., Taylor and Parker, 1959) led us to believe that visualization or spatial abilities would be an important factor

in skilled piloting. Thus, we included a visual interference task to see whether we could impare the better pilots. An auditory interference task was expected to have less interfering effect on the good pilots than the visual interference task.

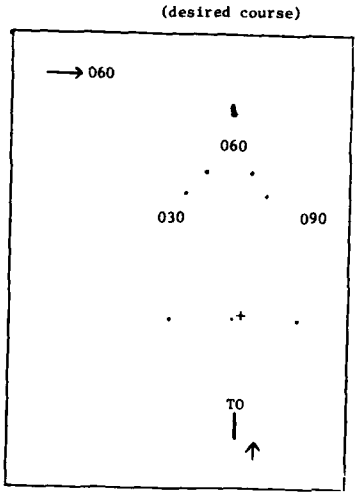
Method

Subjects were recruited from the Lane Community College Flight Technology Program. The trainees ranged from pre-solo to instrument instructor. Information on flight training experience and test scores was gathered. Twenty-four trainees signed up to participate, eighteen came to the first session. However, because of numerous computer failures all of the subjects did not provide data for all conditions. Failures either prevented subjects from finishing a condition or prevented subjects from being tested at all resulting in some subjects refusing to return for later testing. Subjects were paid $3.50 per hour and were promised a bonus if they participated in 18 hours of testing which would have boosted their earning to $5.00/hr.

Work on the simulator was scheduled to take 3 hours. Because of computer problems this was sometimes broken up into two or three different sessions on different days.

(see Figure 1, page following)

The simulation consists of three instruments. One is similar to a directional gyro, one is similar to a turn indicator, one is similar to a course deviation indicator and TO/FROM indicator of a VOR receiver. Note that altitude is not represented in the version of the simulator reported here. Subjects are given successive courses to hold in no wind, no



(directional gyro)

(turn indicator indicating right turn)

(TO/FROM indicator)

(course deviation indicator; course off to right)

CRT SIMULATOR DISPLAY

Figure 1

turbulence conditions (Easy Condition), moderate wind (about 20% of the speed of the plane) and turbulence conditions (Moderate Condition), heavy wind (about 50% of the speed of the plane) and turbulence conditions (Difficult Condition). Simulated wind moved the position of the plane as a vector independent of the heading vector. Simulated turbulence changed the heading. Each individual task set contained 4 courses and if flown perfectly would take about 8 minutes. In practice each took about 10 minutes, depending on skill level, totaling about 90 minutes of simulated time in the three hour session. Subjects controlled the plane's heading by pushing one of two buttons. The longer the button was held down, the steeper the turn. To come out of a turn the opposite button had to be pressed. Subjects were to fly the course as directly as possible, correcting for wind and turbulence as necessary.

After lengthy instructions, subjects were given the easy, moderate and difficult conditions in that order without other tasks. During this time subjects could ask questions and experimenters would make suggestions, as necessary. Next, three sets of medium difficulty simulator tasks were accompanied by an auditory interference task, a visual interference task, and a computation task. The auditory interference task required subjects to say whether the first of two tape-recorded tones was higher or lower than the second. The tone pairs were presented at a rate of 12 per minute. The visual interference task required subjects to keep track of a tic-tac-toe game and to say whether X's or O's won or draw. The tape-recorded task was presented by verbal instructions such as "X in square 7...O in square 2", etc at a rate of about 10 per minute. The computation task required subjects to compute time to the next station given air speed and distance on a 3 x 5 card. Subjects were required to write the time of station passage and the estimate of time to

the next station in fractions of hours and in seconds. The last set of three tasks repeated the sequence of interference tasks used in the second set of three with the only difference being that the difficult simulator conditions were used.

Two of the pilot trainees were beginners with less than 10 hours. They both had a great deal of trouble with the moderate difficulty simulator task, so we did not give them the difficult simulator task. This hurt our correlations because they would certainly have performed poorly had we put them through that ordeal.

Because of the small number of subjects remaining at the end of this primary simulation task, we decided against running more advanced simulation tasks designed to discriminate among more advanced pilots. These tasks include difficult versions of holding patterns, approach patterns and a VOR orientation task.

Results

Our primary interest is in whether the simulator provides a valid measure of piloting skill. We decided on two achievement measures and one judgemental measure, although the later (ratings by the trainee's instructor's) is not yet available. The achievement measures are number of training hours (range between 3 and 150) and rating achieved (range between pre-solo and instrument instructor). Rating achieved has not proven valuable because surviving data are too bunched up in the middle of that small range of five categories.

Data on simulator performance to be reported here are rank orderings of traces of "ground track" relative to desired course. Judgements were subjective based primarily on accuracy and smoothness. Two judges (one with some flying experience, one without) ranked the traces: the average correlation between raters for the different conditions was .92. The two ranks were averaged and the average scores were ranked. Example tracing are shown in Figure II. (See page following).

Recall that there were two levels of simulation task difficulty during which the calculation task was simultaneously administered. Correlation between training hours and simulator performance with the simultaneous calculation task was -.54 for the easier task and -.68 for the difficult task. Since one is the highest rank, the negative correlations with hours of training are as expected. These correlations would be somewhat higher if we have low scores for the two pre-solo pilots who could not complete the difficult simulator conditions.

A few words of caution are in order about interpretation of these high correlations. Much data were lost due to computer failures and subject attrition so that the numbers of observations are small (14 for the easier tasks, 11 for the difficult task, not counting the two beginning pilots who were unable to complete it). Although both of the scores are significant (we are using a t-test with $p < .05$ throughout) the actual values of the correlations should not be taken as good estimates of accounted for variance.

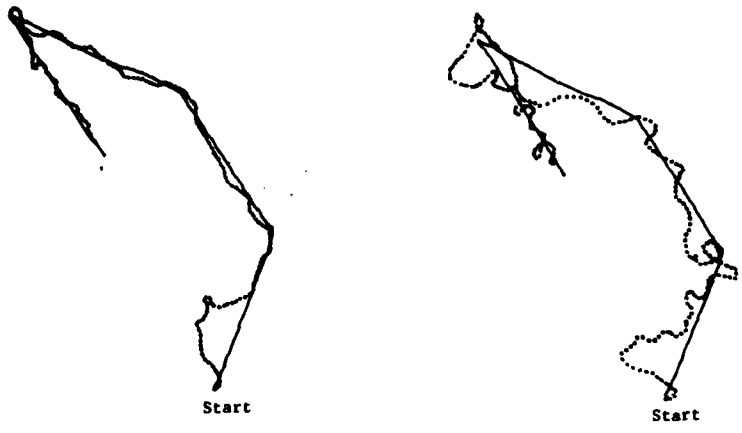


Fig. II Tracings of desired courses (solid line) and actual performance (dotted line ground track). The better tracing is from an instrument instructor with 1000 flying hours including 140 flight training hours. The other tracing is from a private pilot with 60 hours of flying time including 40 hours of training. Tracings are from the most difficult simulator condition and computations were required.

We expected high correlations between the two calculation tasks which differed only in difficulty of the simulator task. The significant correlation was .83.

Since we believed that direction maintenance without task complexity would not be an important predictor, we expected low correlations between the simulator task alone and the combined simulator and calculation tasks. For the moderate difficulty condition the non-significant correlation was .14 for the difficult conditions, however, the significant correlation was .73. Thus it appears that the same subjects are doing well on the difficult conditions regardless of whether or not there is a calculation task for added complexity.

We hoped to gain some insights about coding processes through the use of the interference conditions but the small numbers of data points and possible insensitivity of the rank order data make it unclear whether visual interference was more harmful to experienced pilots than to non-expererienced pilots. There is not a meaningful pattern of significant differences and what data there are do not suggest that visual interference was more important to experienced pilots than auditory interference. We believe that the absolute scores derived from the various statistics which we are recovering from the data will be more sensitive to this matter than ranks. The advanced pilots were so much better than the poorer pilots that the differences caused by interference might not have been great enough to be picked up by changes in ranks.

Discussion

We believe that we have tentative validation of the simulation task; the simulation seems to be sensitive to some of the important aspects of pilot

training. Naturally we would like to have a more complete validation but due to lack of availability of highly skilled pilots we believe that further development is best done at another location.

It seems likely to us that discovering good pilot ability is best done with techniques using information overload. Many pilot tasks are not demanding in most situations. Turning onto a final approach path smoothly, for example, can be done relatively easily by most fairly experienced pilots when there is nothing else to do. On instruments, in turbulence with one or two radios out, and going twice normal speed might make this task more challenging and discriminating of those who can handle bad situations while piloting. This is the sort of challenge that can be set up by a simulation. Another measurement issue is repeatability. One does not have to wait for a windy day to check out cross wind landings or gusty wind landings and such situations are exactly repeatable for measurement considerations. Finally, there is the issue of measurement recording accuracy. One need not judge distance from desired course or smoothness and accuracy of turns by eye. Ground track can be plotted exactly along with other statistics such as numbers of course corrections. Thus the flexible simulator allows more discriminable, repeatable, accurate measurement.

Our current goal is to use the simulator on our readily available subjects to see whether we can predict simulator performance (during training and at assymptotic levels) by performance on other cognitive abilities. The tasks which we have ready to go measure ability to represent visual material, the ability to set priorities, attentional flexibility, and planning ability.

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Footnotes

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Navy

Dr. Ed Aiken
Navy Personnel R&D Center
San Diego, CA 92152

Dr. Arthur Bachrach
Behavioral Sciences Department
Naval Medical Research Institute
Bethesda, MD 20014

CDR Thomas Berghage
Naval Health Research Center
San Diego, CA 92152

Dr. Robert Blanchard
Navy Personnel R&D Center
Management Support Department
San Diego, CA 92151

Dr. Jack R. Borsting
Provost & Academic Dean
U.S. Naval Postgraduate School
Monterey, CA 93940

Dr. Robert Breaux
Code N-71
NAVTRAEQUIPCEN
Orlando, FL 32813

DR. PAT FEDERICO
NAVY PERSONNEL R&D CENTER
SAN DIEGO, CA 92152

Dr. John Ford
Navy Personnel R&D Center
San Diego, CA 92152

Dr. Richard Gibson
Bureau of Medicine and Surgery
Code 512
Navy Department
Washington, DC 20372

CAPT. D.M. GRAGG, MC, USN
HEAD, SECTION ON MEDICAL EDUCATION
UNIFORMED SERVICES UNIV. OF THE
HEALTH SCIENCES
6917 ARLINGTON ROAD
BETHESDA, MD 20014

Navy

MR. GEORGE M. GRAINE
NAVAL SEA SYSTEMS COMMAND
SEA 05L1C2
WASHINGTON, DC 20362

LT Steven D. Harris, MSC, USN
Code 6021
Naval Air Development Center
Warminster, Pennsylvania 18974

CDR Wade Helm
PAC Missile Test Center
Point Mugu, CA 93041

Dr. Lloyd Hitchcock
Human Factors Engineering Division
Naval Air Development Center
Warminster, PA 18974

LCDR Charles W. Hutchins
Naval Air Systems Command
544 Jefferson Plaza # 1
1411 Jefferson Davis Highway
Arlington, VA 20360

CDR Robert C. Kennedy
Naval Aerospace Medical and
Research Lab
Box 29407
New Orleans, LA 70189

CHAIRMAN, LEADERSHIP & LAW DEPT.
DIV. OF PROFESSIONAL DEVELOPMENT
U.S. NAVAL ACADEMYY
ANNAPOLIS, MD 21402

Dr. Kneale Marshall
Scientific Advisor to DCNO(MPT)
OP01T
Washington DC 20370

CAPT Richard L. Martin
USS Francis Marion (LPA-249)
FPO New York, NY 09501

Dr. James McGrath
Navy Personnel R&D Center
Code 306
San Diego, CA 92152

Navy

1 CDR. PFEIFER
FLEET LIAISON OFFICER
AEWBL/FLYING TRAINING DIV.
WILLIAMS AFB, AZ 85224

1 Dr. George Moeller
Chief, Human Factors Branch
Naval Submarine Medical Research Lab
Groton, CN 06340

1 Dr William Montague
Navy Personnel R&D Center
San Diego, CA 92152

1 LCDR W. Moroney
Code 55MP
Naval Postgraduate School
Monterey, CA 93940

1 Commanding Officer
U.S. Naval Amphibious School
Coronado, CA 92155

1 Commanding Officer
Navy [illegible] Research
Center
Patent Library
San Diego, CA 92152

1 Navy Medical [illegible] Command
Code 3
National Navy Medical Center
Bethesda, MD 20014

1 CAPT Paul Nelson, USN
Chief, Naval Medical Corps
Code M
Bureau of Medicine & Surgery
U.S. Department of the Navy
Washington, DC 20372

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San Diego, CA 92152

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Naval Research Laboratory
Code 2627
Washington, DC 20375

1 JOHN OLCER
CHIEF OF NAVAL EDUCATION &
TRAINING SUPPORT
PENSACOLA, FL 32509

1 Psychologist
ONR Branch Office
495 Summer Street
Boston, MA 02210

1 Psychologist
ONR Branch Office
536 S. Clark Street
Chicago, IL 60605

1 Office of Naval Research
Code 200
Arlington, VA 22217

1 Office of Naval Research
Code 441
800 N. Quincy Street
Arlington, VA 22217

1 Director
Engineering Psychology Programs
Code 455
Office of Naval Research
800 N. Quincy Street
Arlington, VA 22217

1 Personnel & Training Research Programs
(Code 458)
Office of Naval Research
Arlington, VA 22217

1 Psychologist
ONR Branch Office
1030 East Green Street
Pasadena, CA 91101

1 Scientific Director
Office of Naval Research
Scientific Liaison Group/Tokyo
American Embassy
APO San Francisco, CA 96503

Navy

1 Office of the Chief of Naval Operations
Research, Development, and Studies Branc
(OP-102)
Washington, DC 20350

1 LT Frank C. Petho, MSC, USNR (Ph.D)
Code L51
Naval Aerospace Medical Research Laborat
Pensacola, FL 32508

1 DR. RICHARD A. POLLAK
ACADEMIC COMPUTING CENTER
U.S. NAVAL ACADEMY
ANNAPOLIS, MD 21402

1 Dr. Gary Poock
Operations Research Department
Naval Postgraduate School
Monterey, CA 93940

Roger W. Remington, Ph.D
Code L52
NAMRL
Pensacola, FL 32508

1 Dr. Bernard Rimland
Navy Personnel R&D Center
San Diego, CA 92152

1 Mr. Arnold Rubenstein
Naval Personnel Support Technology
Naval Material Command (08T244)
Room 1044, Crystal Plaza #5
2221 Jefferson Davis Highway
Arlington, VA 20360

1 Dr. Sam Schiflett
Systems Engineering Test Directorate
U.S. Naval Air Test Center
Patuxent River, MD 20670

1 A. A. SJOHOLM
TECH. SUPPORT, CODE 201
NAVY PERSONNEL R& D CENTER
SAN DIEGO, CA 92152

1 Mr. Robert Smith
Office of Chief of Naval Operations
OP-987E
Washington, DC 20350

1 Dr. Alfred F. Smode
Training Analysis & Evaluation Group
(TAEG)
Dept. of the Navy
Orlando, FL 32813

1 Dr. Richard Sorensen
Navy Personnel R&D Center
San Diego, CA 92152

Army

1 HQ [illegible] Army
TRADOC
USAARENE Director of GEF
APO New York [illegible]

1 Mr. J. Barber
HQS, Department of the Army
DAPE-HRR
Washington, DC [illegible]

1 LTCL Gary Fleischer
Training Effectiveness Analysis Division
HQ Army TRADOC Systems Analysis Activity
White Sands Missile Range, NM [illegible]

1 DR. RALPH DUSEK
U.S. ARMY RESEARCH INSTITUTE
5001 EISENHOWER AVENUE
ALEXANDRIA, VA [illegible]

1 Dr. Ed Johnson
Army Research Institute
5001 Eisenhower Ave.
Alexandria, VA

1 Dr. [illegible]
U.S. ARMY RESEARCH INSTITUTE
5001 EISENHOWER AVENUE
ALEXANDRIA, VA

1 Dr. Patrick [illegible]
Army Research Institute
5001 Eisenhower Ave.
Alexandria, VA

1 Technical Director
U.S. Army Human Engineering Lab
Aberdeen Proving Ground, MD

1 Dr. Harold F. O'Neil, Jr.
ATTN: PERI-OK
Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA

Army

1 Dr. Robert [illegible]
U. S. Army Research Institute for the
Behavioral and Social Sciences
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Director, Training Development
U.S. Army Administration Center
ATTN: Dr. Cherrill
Ft. Benjamin Harrison, IN 46216

1 Dr. Joseph Ward
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

Air Force

1 Air Force Human Resources Lab
AFHRL/PED
Brooks AFB, TX 78235

1 U.S. Air Force Office of Scientific
Research
Life Sciences Directorate, NL
Bolling Air Force Base
Washington, DC 20332

1 Dr. Earl A. Alluisi
HQ, AFHRL (AFSC)
Brooks AFB, TX 78235

1 DR. G. A. ECKSTRAND
AFHRL/AS
WRIGHT-PATTERSON AFB, OH 45433

1 Dr. Genevieve Haddad
Program Manager
Life Sciences Directorate
AFOSR
Bolling AFB, DC 20332

1 AFHRL/FT (Dr. Ron Hughes)
Williams AFB, AZ 85224

1 Dr. Marty Rockway (AFHRL/TT)
Lowry AFB
Colorado 80230

2 Faculty Development Division
Headquarters Sheppard Technical
Training Center (ATC)
Sheppard AFB, TX 76311

1 Jack A. Thorpe, Maj., USAF
Naval War College
Providence, RI 02846

Marines

1 H. William Greenup
Education Advisor (E031)
Education Center, MCDEC
Quantico, VA 22134

1 Special Assistant for Marine
Corps Matters
Code 100M
Office of Naval Research
800 N. Quincy St.
Arlington, VA 22217

1 DR. A.L. SLAFKOSKY
SCIENTIFIC ADVISOR (CODE RD-1)
HQ, U.S. MARINE CORPS
WASHINGTON, DC 20380

Civil Govt

1 Dr. Susan Chipman
Basic Skills Program
National Institute of Education
1200 19th Street NW
Washington, DC 20208

1 Dr. Joseph I. Lipson
Division of Science Education
Room W-638
National Science Foundation
Washington, DC 20550

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Science Education Dev.
and Research
National Science Foundation
Washington, DC 20550

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Memory & Cognitive Processes
National Science Foundation
Washington, DC 20550

Non Govt

1 Dr. John R. Anderson
Department of Psychology
Carnegie Mellon University
Pittsburgh, PA 15213

1 Dr. John Annett
Department of Psychology
University of Warwick
Coventry CV4 7AL
ENGLAND

1 DR. MICHAEL ATWOOD
SCIENCE APPLICATIONS INSTITUTE
40 DENVER TECH. CENTER WEST
7935 E. PRENTICE AVENUE
ENGLEWOOD, CO 80110

1 1 psychological research unit
Dept. of Defense (Army Office)
Campbell Park Offices
Canberra ACT 2600, Australia

1 Dr. Alan Baddeley
Medical Research Council
Applied Psychology Unit
15 Chaucer Road
Cambridge CB2 2EF
ENGLAND

1 Dr. Patricia Baggett
Department of Psychology
University of Denver
University Park
Denver, CO 80208

1 Mr Avron Barr
Department of Computer Science
Stanford University
Stanford, CA 94305

1 Dr. Jackson Beatty
Department of Psychology
University of California
Los Angeles, CA 90024

1 Dr. [illegible]
Dept. of Psychology
Sacramento State College
[illegible] Jay Street
Sacramento, CA [illegible]

1 Dr. Lyle [illegible]
Department of Psychology
University of Colorado
Boulder, CO [illegible]

1 Dr. Bruce [illegible]
Department of Computer Science
Stanford University
Stanford, CA 94305

1 Dr. John B. Carroll
Psychometric Lab
Univ. of No. Carolina
Davie Hall 013A
Chapel Hill, NC [illegible]

1 Center for [illegible] Study of [illegible]
[illegible]
51 Gerty Drive
Champaign, IL [illegible]

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Livingstone Road
Stratford
London E15 2LJ
ENGLAND

1 Dr. William Chase
Department of Psychology
Carnegie Mellon University
Pittsburgh, PA 15213

1 Dr. Micheline Chi
Learning R & D Center
University of Pittsburgh
3939 O'Hara Street
Pittsburgh, PA [illegible]

1 Dr. William Clancey
Department of Computer Science
Stanford University
Stanford, CA [illegible]

1 Dr. [illegible]
Bolt Beranek & Newman, Inc.
[illegible]
Cambridge, MA [illegible]

1 Dr. Meredith P. [illegible]
[illegible]
[illegible] Street, N.W.
Washington, DC [illegible]

1 Dr. [illegible]
[illegible], Inc.
P.O. Drawer [illegible]
Santa Barbara, CA [illegible]

1 Director, Human Factors [illegible]
Defence & Civil Institute of
Environmental Medicine
Post Office Box [illegible]
Downsview, Ontario [illegible]
CANADA

1 Dr. Emmanuel Donchin
Department of Psychology
University of Illinois
Champaign, IL [illegible]

1 MAJOR [illegible] EVANS
CANADIAN FORCES [illegible]
[illegible] AVENUE [illegible]
TORONTO, ONTARIO, CANADA

1 Dr. [illegible]
Bolt Beranek & Newman, Inc.
50 Moulton St.
Cambridge, MA [illegible]

1 Dr. Victor Fields
Dept. of Psychology
Montgomery College
Rockville, MD [illegible]

1 Dr. Edwin A. Fleishman
Advanced Research [illegible]
Suite [illegible]
[illegible]
Washington, DC [illegible]

Non Govt

1 Dr. John R. Frederiksen
Bolt Beranek & Newman
50 Moulton Street
Cambridge, MA 02138

1 Dr. Alinda Friedman
Department of Psychology
University of Alberta
Edmonton, Alberta
CANADA T6G 2J9

1 Dr. R. Edward Geiselman
Department of Psychology
University of California
Los Angeles, CA 90024

1 DR. ROBERT GLASER
LRDC
UNIVERSITY OF PITTSBURGH
3939 O'HARA STREET
PITTSBURGH, PA 15213

1 Dr. Marvin D. Glock
Department of Education
Stone Hall
Cornell University
Ithaca, NY 14853

1 Dr. Daniel Gopher
Industrial & Management Engineering
Technion-Israel Institute of Technology
Haifa
ISRAEL

1 DR. JAMES G. GREENO
LRDC
UNIVERSITY OF PITTSBURGH
3939 O'HARA STREET
PITTSBURGH, PA 15213

1 Dr. Harold Hawkins
Department of Psychology
University of Oregon
Eugene OR 97403

Dr. Barbara Hayes-Roth
The Rand Corporation
1700 Main Street
Santa Monica, CA 90406

Non Govt

1 Dr. Frederick Hayes-Roth
The Rand Corporation
1700 Main Street
Santa Monica, CA 90406

1 Dr. James R. Hoffman
Department of Psychology
University of Delaware
Newark, DE 19711

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27857 Berwick Drive
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Dept. of Psychology
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1200 17th Street N.W.
Washington, DC 20036

1 Dr. Steven W. Keele
Dept. of Psychology
University of Oregon
Eugene, OR 97403

1 Dr. Walter Kintsch
Department of Psychology
University of Colorado
Boulder, CO 80302

1 Dr. David Kieras
Department of Psychology
University of Arizona
Tucson, AZ 85721

1 Dr. Kenneth Kilvington
Alfred P. Sloan Foundation
630 Fifth Avenue
New York, NY 10020

Non Govt

1 Dr. Robert J. Seidel
Instructional Technology Group
HumRRO
300 N. Washington St.
Alexandria, VA 22314

1 Dr. Robert Smith
Department of Computer Science
Rutgers University
New Brunswick, NJ 08903

1 Dr. Richard Snow
School of Education
Stanford University
Stanford, CA 94305

1 Dr. Kathryn T. Spoehr
Department of Psychology
Brown University
Providence, RI 02912

1 Dr. Robert Sternberg
Dept. of Psychology
Yale University
Box 11A, Yale Station
New Haven, CT 06520

1 Dr. Albert Stevens
Bolt Beranek & Newman, Inc.
50 Moulton Street
Cambridge, MA 02138

1 Dr. Thomas Sticht
HumRRO
300 N. Washington Street
Alexandria, VA 22314

Dr. David Stone
ED 2[illegible]
SUNY, Albany
Albany, NY 12222

1 Dr. Patrick Suppes
Institute for Mathematical Studies in
The Social Sciences
Stanford University
Stanford, CA 94305

Non Govt

1 Dr. Kikumi Tatsuoka
Computer Based Education Research
Laboratory
252 Engineering Research Laboratory
University of Illinois
Urbana, IL 61801

1 Dr. John Thomas
IBM Thomas J. Watson Research Center
P.O. Box 218
Yorktown Heights, NY 10598

1 Dr. Perry Thorndyke
The Rand Corporation
1700 Main Street
Santa Monica, CA 90406

1 Dr. Douglas Towne
Univ. of So. California
Behavioral Technology Labs
3717 South Hope Street
Los Angeles, CA 90007

1 Dr. J. Uhlaner
Perceptronics, Inc.
6271 Variel Avenue
Woodland Hills, CA 91364

1 Dr. Benton J. Underwood
Dept. of Psychology
Northwestern University
Evanston, IL 60201

1 Dr. William R. Uttal
University of Michigan
Institute for Social Research
Ann Arbor, MI 48106

1 Dr. Phyllis Weaver
Graduate School of Education
Harvard University
200 Larsen Hall, Appian Way
Cambridge, MA 02138

1 Dr. David J. Weiss
N660 Elliott Hall
University of Minnesota
75 E. River Road
Minneapolis, MN 55455